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ENVIRONMENTAL PROTECTION AGENCY

[EPA-HQ-OAR-2011-0542; FRL-9608-8]

Notice of Data Availability Concerning Renewable Fuels Produced from Palm Oil under the RFS Program

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of Data Availability (NODA).

SUMMARY: This Notice provides an opportunity to comment on EPA's analyses of palm oil used as a feedstock to produce biodiesel and renewable diesel under the Renewable Fuel Standard (RFS) program. EPA's analysis of the two types of biofuel shows that biodiesel and renewable diesel produced from palm oil have estimated lifecycle greenhouse gas (GHG) emission reductions of 17% and 11% respectively for these biofuels compared to the statutory baseline petroleum-based diesel fuel used in the RFS program. This analysis indicates that both palm oil-based biofuels would fail to qualify as meeting the minimum 20% GHG performance threshold for renewable fuel under the RFS program.

DATES: Comments must be received on or before [insert date 30 days after publication in the Federal Register.]

ADDRESSES: Submit your comments, identified by Docket ID No. EPA-HQ-OAR-2011-0542, by one of the following methods:

- www.regulations.gov: Follow the on-line instructions for submitting comments.
- Email: asdinfo@epa.gov
- Mail: Air and Radiation Docket and Information Center, Environmental Protection Agency, Mailcode: 2822T, 1200 Pennsylvania Ave., NW., Washington, DC 20460.
- Hand Delivery: Air and Radiation Docket and Information Center, EPA/DC, EPA West, Room 3334, 1301 Constitution Ave., NW, Washington DC 20004. Such deliveries are only accepted during the Docket's normal hours of operation, and special arrangements should be made for deliveries of boxed information.

Instructions: Direct your comments to Docket ID No. EPA-HQ-OAR-2011-0542. EPA's policy is that all comments received will be included in the public docket without change and may be made available online at www.regulations.gov, including any personal information provided, unless the comment includes information claimed to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Do not submit information that you consider to be CBI or otherwise protected through www.regulations.gov or asdinfo@epa.gov. The www.regulations.gov website is an "anonymous access" system, which means EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an e-mail comment directly to EPA without going through www.regulations.gov your e-mail address will be automatically captured and included as part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD-ROM you submit. If EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses. For additional information about EPA's public docket visit the EPA Docket Center homepage at http://www.epa.gov/epahome/dockets.htm.

Docket: All documents in the docket are listed in the www.regulations.gov index. Although listed in the index, some information is not publicly available, e.g., CBI or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, will be publicly available only in hard copy. Publicly available docket materials are available either electronically in www.regulations.gov or in hard copy at the Air and Radiation Docket and Information Center, EPA/DC, EPA West, Room 3334, 1301 Constitution Ave., NW, Washington, DC 20004. The Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566-1744, and the telephone number for the Air Docket is (202) 566-1742.

FOR FURTHER INFORMATION CONTACT: Aaron Levy, Office of Transportation and Air Quality, Transportation and Climate Division, Environmental Protection Agency, 1200 Pennsylvania Ave., NW, Washington, DC 20460 (MC: 6041A); telephone number: 202-564-2993; fax number: 202-564-1177; email address: levy.aaron@epa.gov.

SUPPLEMENTARY INFORMATION:

Outline of This Preamble

I. General Information

A. *Does this Action Apply to Me?*

Entities potentially affected by this action are those involved with the production, distribution, and sale of transportation fuels, including gasoline and diesel fuel or renewable fuels such as biodiesel and renewable diesel. Regulated categories include:

Category	NAICS[1] Codes	SIC[2] Codes	Examples of Potentially Regulated Entities
Industry	324110	2911	Petroleum Refineries
Industry	325193	2869	Ethyl alcohol manufacturing
Industry	325199	2869	Other basic organic chemical manufacturing
Industry	424690	5169	Chemical and allied products merchant wholesalers
Industry	424710	5171	Petroleum bulk stations and terminals
Industry	424720	5172	Petroleum and petroleum products merchant wholesalers
Industry	454319	5989	Other fuel dealers

[1] North American Industry Classification System (NAICS)
[2] Standard Industrial Classification (SIC) system code.

This table is not intended to be exhaustive, but rather provides a guide for readers regarding entities likely to engage in activities that may be affected by today's action.   To determine whether your activities would be affected, you should carefully examine the applicability criteria in 40 CFR Part 80, Subpart M. If you have any questions regarding the applicability of this action to a particular entity, consult the person listed in the preceding section.

B. *What Should I Consider as I Prepare My Comments for EPA?*

1. *Submitting CBI.* Do not submit this information to EPA through www.regulations.gov or e-

mail. Clearly mark the part or all of the information that you claim to be CBI. For CBI information in a disk or CD ROM that you mail to EPA, mark the outside of the disk or CD ROM as CBI and then identify electronically within the disk or CD ROM the specific information that is claimed as CBI. In addition to one complete version of the comment that includes information claimed as CBI, a copy of the comment that does not contain the information claimed as CBI must be submitted for inclusion in the public docket. Information so marked will not be disclosed except in accordance with procedures set forth in 40 CFR part 2.

2. *Tips for Preparing Your Comments.* When submitting comments, remember to:

- Identify the rulemaking by docket number and other identifying information (subject heading, Federal Register date and page number).
- Follow directions - The agency may ask you to respond to specific questions or organize comments by referencing a Code of Federal Regulations (CFR) part or section number.
- Explain why you agree or disagree; suggest alternatives and substitute language for your requested changes.
- Describe any assumptions and provide any technical information and/or data that you used.
- If you estimate potential costs or burdens, explain how you arrived at your estimate in sufficient detail to allow for it to be reproduced.
- Provide specific examples to illustrate your concerns, and suggest alternatives.
- Explain your views as clearly as possible, avoiding the use of profanity or

personal threats.

- Make sure to submit your comments by the comment period deadline identified.

II. Analysis of Lifecycle Greenhouse Gas Emissions

A. Methodology

1. *Scope of Analysis*

On March 26, 2010, the Environmental Protection Agency (EPA) published changes to the Renewable Fuel Standard program regulations as required by 2007 amendments to CAA 211(o). This rulemaking is commonly referred to as the "RFS2" final rule. As part of the RFS2 final rule we analyzed various categories of biofuels to determine whether the complete lifecycle GHG emissions associated with the production, distribution, and use of those fuels meet minimum lifecycle greenhouse gas reduction thresholds as specified by CAA 211(o) (i.e., 60% for cellulosic biofuel, 50% for biomass-based diesel and advanced biofuel, and 20% for other renewable fuels). Our final rule focused our lifecycle analyses on fuels that were anticipated to contribute relatively large volumes of renewable fuel by 2022 and thus did not cover all fuels that either are contributing or could potentially contribute to the program. In the preamble to the final rule EPA indicated that it had not completed the GHG emissions impact analysis for several specific biofuel production pathways but that this work would be completed through a supplemental rulemaking process. Since the March 2010 final rule was issued, we have continued to examine several additional pathways not analyzed for the final rule. This Notice of Data Availability ("NODA") focuses on our analysis of the palm oil biodiesel and palm oil renewable diesel pathways. The modeling approach EPA used in this analysis is the same general approach used in the final RFS2 rule for lifecycle analyses of other biofuels.[1] The RFS2 final rule preamble and Regulatory Impact Analysis (RIA) provides further discussion of our approach.

This Notice provides an opportunity to comment on EPA's analyses of lifecycle GHG emissions related to the production and use of biodiesel and renewable diesel produced from palm oil feedstock. We intend to consider all of the relevant comments received. In general, comments will be considered relevant if they pertain to EPA's analysis of lifecycle GHG emissions related to palm oil biofuels, and especially if they provide specific information for consideration in our modeling. When all relevant comments have been considered we intend to inform the public of any resulting revisions in our analyses or any other relevant information pertaining to our consideration of the comments received. Public notification regarding our consideration of comments could be accomplished in several formats, such as a Federal Register notice, a rulemaking action or a guidance document. The appropriate form of public notification will depend on the outcome of the public comment process and any reanalysis we deem appropriate. In the event that EPA does not significantly modify its analyses, no regulatory amendments will be necessary since the existing regulations currently do not identify any palm oil-based biofuel production pathways as satisfying minimum lifecycle GHG reduction requirements.

2. *Models Used*

[1] U.S. Environmental Protection Agency (EPA). 2011. Summary of Modeling Inputs and Assumptions for the Notice of Data Availability (NODA) Concerning Renewable Fuels Produced from Palm Oil under the Renewable Fuel Standard (RFS) Program. Memorandum to Air and Radiation Docket EPA-HQ-OAR-2011-0542

EPA's analysis of the palm oil biodiesel and renewable diesel pathways uses the same model of international agricultural markets that was used for the final RFS2 rule: the Food and Agricultural Policy and Research Institute international models as maintained by the Center for Agricultural and Rural Development at Iowa State University (the FAPRI-CARD model). For more information on the FAPRI-CARD model refer to the RFS2 final rule preamble (75 FR 14670) or the RFS2 Regulatory Impact Analysis (RIA).[2] These documents are available in the docket or online at *http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm*. The models require a number of inputs that are specific to the pathway being analyzed, including projected yields of feedstock per acre planted, projected fertilizer use, and energy use in feedstock processing and fuel production. The docket includes detailed information on model inputs, assumptions, calculations, and the results of our assessment of the lifecycle GHG emissions performance for palm oil biodiesel and renewable diesel.

As in our analysis of sugarcane ethanol in the RFS2 final rule, we did not use the Forestry and Agricultural Sector Optimization Model (FASOM) in our analysis of palm oil biodiesel and renewable diesel. FASOM is a highly detailed partial equilibrium model of the United States agricultural and forestry sectors. In the RFS2 final rule FASOM was used to determine the domestic U.S. agricultural sector impacts of domestically grown biofuel feedstocks. As palm oil is not grown domestically in any significant volume, the FAPRI-CARD model was the only model of agricultural markets used in the analysis. Our modeling indicates that any impacts to U.S. agriculture from using palm oil for biofuel production are small in comparison to the

[2] EPA. 2010. Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. EPA-420-R-10-006. http://www.epa.gov/oms/renewablefuels/420r10006.pdf

international impacts.[3] Therefore, we determined that for this analysis the FAPRI-CARD model is better suited for modeling domestic agricultural impacts and, as such, FASOM modeling is unnecessary.

3. *Scenarios Modeled*

To assess the impacts of an increase in renewable fuel volume from business-as-usual (what is likely to have occurred without the RFS biofuel mandates) to levels required by the statute, we established reference and control cases for a number of biofuels analyzed for the RFS2 final rulemaking. The reference case includes a projection of renewable fuel volumes without the RFS renewable fuel volume mandates. The control cases are projections of the volumes of renewable fuel that might be used in the future to comply with the volume mandates. The final rule reference case volumes were based on the Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2007 reference case projections. In the RFS2 rule, for each individual biofuel, we analyzed the incremental GHG emission impacts of increasing the volume of that fuel to the total mix of biofuels needed to meet the EISA requirements. Rather than focus on the GHG emissions impacts associated with a specific gallon of fuel and tracking inputs and outputs across different lifecycle stages, we determined the overall aggregate impacts across sectors of the economy in response to a given volume change in the amount of biofuel produced. For this analysis we compared impacts in the control case to the impacts in a new palm oil biofuel case.

[3] For example, in the scenarios modeled only 1% of land use change GHG emissions originate in the United States. These results are discussed more below and in the supporting materials available through the docket.

Our “control” case volumes are based on projections of a feasible set of fuel types and feedstocks. The control case for our modeling assumes no renewable fuel made from palm oil is used in the United States. For the “palm biofuel” case, our modeling assumes approximately 200 million gallons of biodiesel and 200 million gallons of renewable diesel from palm oil are used in the United States in the year 2022. The modeled scenario includes 1.46 million metric tonnes (MMT) of crude palm oil used as feedstock to produce the additional 400 million gallons of palm oil biofuel in 2022. The projected lifecycle GHG emissions associated with this increased production and use of palm oil biofuel in 2022 are normalized per tonne of crude palm oil. The lifecycle GHG emissions per gallon of biofuel are then calculated based on the yields of biodiesel and renewable diesel per tonne of crude palm oil.

Our volume scenario of approximately 200 million gallons of biodiesel and 200 million gallons of renewable diesel from palm oil in 2022 is based on several factors including historical volumes of palm oil production, potential feedstock availability and other competitive uses (e.g., for food or export elsewhere instead of for U.S. transportation fuel). Our assessment is described further in the inputs and assumptions document that is available through the docket (EPA 2011). Based in part on consultation with experts at the United States Department of Agriculture (USDA) and industry representatives, we believe that these volumes are reasonable for the purposes of evaluating the impacts of producing biodiesel and renewable diesel from palm oil.

The FAPRI-CARD model, described above, projects in which countries the palm oil will most likely be grown to supply these biofuel volumes to the U.S. based on the relative economics of palm oil production, yield trends in different regions and other factors. Palm oil is currently grown in several regions internationally but the vast majority, close to 90%, is produced in Indonesia and Malaysia. Our modeled scenario projects that Indonesia and Malaysia would be the primary suppliers of palm oil for use as biofuel feedstocks, with other regions, such as Africa, Thailand and South America, contributing much smaller amounts. Because we anticipate that the great majority of palm oil for use in biofuels would be produced in Indonesia and Malaysia our modeling efforts focus on evaluating the lifecycle GHG emissions associated with palm oil production in these countries.

Table II-1 provides a summary of projected palm oil production in 2022 according to the FAPRI-CARD model.[4] As discussed above, in the palm biofuel case 1.46 MMT of additional palm oil is used as biofuel feedstock in 2022 as compared to the control case. We project that global palm oil production would expand by 0.562 MMT in the palm biofuel case; the remaining volume of palm oil for biofuel production would be diverted from other sectors, such as food and chemical uses. In response we project that production of other vegetable oils would increase to back fill the palm oil diverted to the biofuels industry (See Table II-2). Due to market-mediated responses vegetable oil production does not increase enough to make up for the full amount of palm oil diverted to biofuel production in the palm biofuel case. There are several explanations for this including demand substitution away from vegetable oils and towards other products such as grains, meat and dairy. For more information refer to the full results from the FAPRI-CARD model which are available through the docket.

Table II-1. Projected Palm Oil Production in 2022 (Thousand Metric Tonnes)

[4] In the tables throughout this preamble totals may not sum due to rounding errors and negative numbers are commonly listed in parentheses.

	Control Case	Palm Biofuel Case	Difference
Indonesia	31,254	31,575	321
Malaysia	25,992	26,196	204
Rest of World	7,739	7,777	38
World	64,986	65,548	562

Table II-2. Projected Vegetable Oil Production in 2022 (Thousand Metric Tonnes)

	Control Case	Palm Biofuel Case	Difference
Palm Oil	64,986	65,548	562
Soybean Oil	308,553	308,620	67
Rapeseed/Canola Oil	68,845	68,963	118
Other Vegetable Oils*	28,219	28,317	97
Total	470,603	471,448	845

* Includes cottonseed oil, peanut oil, sunflower oil and palm kernel oil

As shown in the tables above, the primary response in the scenarios modeled is to increase palm oil production in Malaysia and Indonesia. In our analysis, projected palm oil yields in 2022 are approximately 5 tonnes per hectare in both Indonesia and Malaysia. The EPA projection for palm oil yields is an extension of the historical data trend forward to 2022, based on historical data from the USDA.[5] Palm oil yields vary in other countries, but in general they are somewhat less than the yields achieved in Indonesia and Malaysia. (More information on projected palm oil yields is available in the inputs and assumptions document available through

[5] Historical palm oil yields are based on data from USDA's Production, Supply and Distribution (PSD) database and reports from USDA's Global Agricultural Information Network (GAIN).

the docket.) Projected harvested areas of palm oil are reported in Table II-3. As discussed below, the land use change GHG emissions associated with the incremental expansion of palm oil areas in Indonesia and Malaysia are a focal point in our analysis.

Table II-3. Projected Palm Oil Harvested Area in 2022 (Thousand Harvested Hectares)

	Control Case	Palm Biofuel Case	Difference
Indonesia	6,179	6,243	63
Malaysia	5,202	5,242	41
Rest of World	4,035	4,055	20
World	15,416	15,504	124

4. Analysis of Projected Land Use Changes in Indonesia and Malaysia

As in our analysis of other feedstocks in the RFS2 final rule, we assessed what the GHG emissions impacts would be relating to palm oil production (including land use changes) due to the use of additional volumes of palm oil for biofuel production. Today's assessment of palm oil as a biofuel feedstock considers GHG emissions from international land use changes related to the production and use of palm oil, and uses the same land use change modeling approach used in the final RFS2 rule for analyses of other biofuel pathways. However, given our focus today on the use of palm oil as a biofuel feedstock, this analysis for palm oil is more detailed and considers new data for Indonesia and Malaysia, including higher resolution satellite imagery and maps of relevant geographic features, such as the location of existing oil palm plantations, soil types, roads, etc. EPA decided to undertake a more detailed assessment of Malaysia and Indonesia as compared to other regions, based on a number of factors including the concentration of the palm oil industry in this region and the availability of new data on palm oil land use.

The goal of our Indonesia and Malaysia land use change analysis is to estimate GHG emissions from the incremental expansion of palm oil plantations that would result from the increased demand for palm oil to produce the modeled 400 million gallons of biodiesel and renewable diesel (i.e., land use change GHG emissions in Indonesia and Malaysia in the palm biofuel case versus the control case). This analysis involved projecting the locations of future palm oil expansion, the types of land impacted and the resulting GHG emissions. First, we gathered spatially explicit data on factors that could be expected to influence the location of palm oil plantations. In our analysis the spatial data are analyzed using the GEOMOD land use change simulation model, described in more detail below, to project the locations of incremental palm oil expansion in the scenarios modeled. We used the latest available data to set land conversion GHG emissions factors for Indonesia and Malaysia. Finally, we considered the uncertainty in our estimates and factor that into our assessment of threshold determinations for palm oil biodiesel and palm oil renewable diesel. An overview of our Indonesia and Malaysia land use change analysis is provided below, including references to materials that are available through the docket which provide more details about all of the inputs, assumptions and results.

A key input in our analysis is newly available data on the historic locations of palm oil cultivation. These data are important because they establish a baseline area where palm oil is currently grown or has been grown in recent years. Past changes in the location of palm oil plantations were evaluated using relevant spatial information to determine what geographic factors were correlated with the changes. We then used this new understanding to predict the locations of future expansion related to increased palm oil biofuel production. This section includes the following:

- Description of data on the location of palm oil plantations in Indonesia and Malaysia;
- Summary of the geographic data sources considered in our analysis;
- Background on the GEOMOD model and our methodology for land use change projections;
- Summary of projected locations for palm oil expansion;
- Description of land use change emissions factors used in our analysis; and
- Estimated land use change GHG emissions in the scenarios modeled.

Data on the historic locations of palm oil plantations in Indonesia and Malaysia – For Indonesia a literature search was conducted which found an absence of available spatial data on the locations of palm oil plantations. To fill this data gap EPA developed such maps for the time period from 2000 to 2009 using satellite imagery and other remotely sensed information. As described below, the mapping project required intensive effort in terms of both data analysis and visual inspection. To enhance data quality and mapping accuracy we limited the geographic scope of the project to the islands of Sumatra and Kalimantan where close to 90% of Indonesia's palm oil is known to be located.[6] In recent years palm oil expansion has also been encouraged in more remote locations on the islands of Sulawesi and Papua, but as mentioned above our

[6] USDA Foreign Agricultural Service (USDA-FAS). 2009. Indonesia: Palm Oil Production Growth To Continue. Commodity Intelligence Report. http://www.pecad.fas.usda.gov/highlights/2009/03/Indonesia/

mapping efforts did not consider these islands. This source of uncertainty in our analysis is discussed in a reference document available through the public docket which describes our consideration of uncertainty.

To map the location of palm oil plantations in Indonesia we leveraged data from the complete Landsat archive, high-resolution data via Google Earth, and data from the National Geospatial-Intelligence Agency (NGA) Unclassified National Informational Library (UNIL), among others. Analysis of palm oil plantation areas using Landsat data was performed both visually and through an automated detection algorithm to ensure a robust analysis. The project mitigated cloud cover and data gaps, executed final plantation identification, and estimated the total area of medium- to large-scale oil palm plantations. Using high-resolution remote sensing data yielded an estimated ground cover area for oil palm of 3.2 million hectares in the year 2000 and 4.0 million hectares in the year 2009. Detailed documentation of the analysis as well as electronic maps showing the results are available through the docket.[7,8]

For Malaysia, data on the locations of palm oil plantations in 2003 and 2009 were provided by the Malaysian Palm Oil Board (MPOB), an agency of the Malaysian government. The data were provided in the form of electronic maps showing mature and immature palm oil plantations. The map of 2003 palm oil plantations utilizes remote sensing data from the Landsat database,[9] and the map of 2009 plantations is based on SPOT satellite images.[10] The data show

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7 Integrity Applications Incorporated (IAI). 2010. High Resolution Land Use Change Analysis of Oil Palm in Sumatra and Kalimantan Circa 2010. Report to EPA. BPA-09-03. September 20, 2010.
8 IAI. 2011. High Resolution Land Use Change Analysis for Sumatra and Kalimantan Circa 2000. Report to EPA. BPA-09-03. April 8, 2011.
9 Wahid, B. O., Nordiana, A. Aand Tarmizi, A., M. 2005. Satellite Mapping of Oil Palm Land Use. MPOB Information Series. June 2005

the location of roughly 3.8 million hectares of palm oil plantations in 2003 and roughly 5.2 million hectares in 2009. The original maps, in a format compatible with Geographic Information System (GIS) software, were provided under a claim of confidential business information (CBI) and then returned to the source. Therefore, the original files are not available for public review. However, based on our agreement with the MPOB, electronic image files depicting the maps are available for review in the public docket.

Spatial analysis of land use change in Indonesia and Malaysia – In addition to the historic locations of palm oil plantations, our analysis considers other relevant geographic suitability factors for Indonesia and Malaysia. For our analysis of land use change in Indonesia fourteen factor maps were created: elevation, precipitation, temperature, slope, soil type, land cover type in 2001, distance to roads, distance to rivers, distance to railroads, distance to settlements, distance to palm oil mills, peat soil location, land allocation (e.g., protected areas), and distance to existing plantations. For our analysis of Malaysia eleven factor maps were created: elevation, precipitation, temperature, slope, soil type, land cover type in 2001, distance to roads, distance to rivers, distance to railroads, distance to settlements, and distance to existing plantations. The factor maps were selected based on data availability and their relevance for projecting the location of future palm oil plantations. More details about the data used in our projections, including the source for each data element, are provided in technical reports available through the docket.[11,12] We welcome public comments on additional data sources for consideration in our modeling.

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[10] MPOB. 2010. Additional Information Requested by United States Environmental Protection Agency: Agricultural Input. Data submitted by MPOB. June 4, 2010

[11] Harris, N., and Grimland, S. 2011a. Spatial Modeling of Future Oil Palm Expansion in Indonesia, 2000 to 2022. Winrock International. Draft report submitted to EPA.

[12] Harris, N., and Grimland, S. 2011b. Spatial Modeling of Future Oil Palm Expansion in Malaysia, 2003 to 2022. Winrock International. Draft report submitted to EPA.

To analyze the spatial data described above and use it to project the most likely locations for future palm oil expansion, we used a well-established land use change simulation model called GEOMOD. GEOMOD is a spatially explicit simulation model of land cover change that uses maps of bio-geophysical attributes and of existing land cover to extrapolate the known pattern of land cover from one point in time to other points in time. GEOMOD was developed by researchers at the SUNY College of Environmental Science and Forestry with funding from the U.S. Department of Energy.[13] It has been used to model land cover changes across the world in many different ecosystems including Costa Rica,[14] Indonesia[15] and India.[16]

Using spatial data described above, the GEOMOD land use change simulation model was used to project the locations of future palm oil expansion in Indonesia and Malaysia until the year 2022. First, we created maps of factors that could influence where future palm oil expansion occurs, such as elevation, slope, proximity to roads, etc. Second, we compared the factor maps against a map of existing palm oil plantations in 2000 and 2003 for Indonesia and Malaysia respectively to construct a series of suitability maps. In the calibration stage, for each suitability map the model assigned higher suitability values to locations that have a combination of characteristics similar to the land already cultivated in palm oil and low suitability values to locations that are less similar to existing palm oil areas. In the validation stage, each candidate suitability map was overlain with a map of existing plantations in the year 2009. Each suitability

[13] Hall, C., A., S., Tian, H., Qi, Y., Pontius, R., G., Cornell, J., and Uhlig, J. 1995. Modeling spatial and temporal patterns of tropical land use change. Journal of Biogeography, 22, 753-757.
[14] Pontius Jr., R. G., Cornell, J., and Hall, C. 2001. Modeling the spatial pattern of land-use change with Geomod2: application and validation for Costa Rica. Agriculture, Ecosystems & Environment 85(1-3) p.191-203.
[15] Harris, N. L, Petrova, S., Stolle, S., and Brown, S. 2008. Identifying optimal areas for REDD intervention: East Kalimantan, Indonesia as a case study. Environmental Research Letters 3: 035006.
[16] Rashmi, M. and Lele, N. 2010. Spatial modeling and validation of forest cover change in Kanakapura region using GEOMOD. Journal of the Indian Society of Remote Sensing p.45-54.

map was evaluated with a set of statistics to assess its ability to accurately project the location of palm oil areas from the first time period to the second time period, e.g., 2000 to 2009.

After single factor suitability maps were tested, we used this information to create suitability maps from several combined factors and with different weighting schemes. Results from the validation procedures of each scenario were used to refine subsequent simulations until a simulation model achieved the best validation results. The best model was defined as the model that most accurately projects the location of palm oil expansion between the first and second time periods. When the best model was identified based on the validation exercises, we used this model to simulate expansion of oil palm plantations from 2000 to 2022 in Indonesia and from 2003 to 2022 in Malaysia.

For this analysis 34 different suitability maps were created for Indonesia. After applying lessons learned from the Indonesia analysis we were able to narrow the field to 18 different suitability maps for Malaysia. After all of the trials, in both countries the combined suitability map that weighted all of the factors equally performed the best across a number of accuracy metrics. For both countries the accuracy metrics for the selected suitability maps indicated good model performance. Thus, the suitability maps created by weighting all factors equally were chosen to simulate expansion of oil palm plantations to 2022 in Indonesia and Malaysia. More details about our GEOMOD analysis are provided in technical reports available through the docket.[17]

Projected land use changes in Malaysia and Indonesia – This section provides a

[17] Harris et al. (2011a) and (2011b)

summary of our results regarding projected land use changes in Indonesia and Malaysia. As discussed above, we used the FAPRI-CARD model to simulate a roughly 400 million gallon increase in palm oil biodiesel and renewable diesel production in 2022, resulting in additional palm oil harvested area in Indonesia and Malaysia of 63 and 41 thousand hectares respectively. Using the GEOMOD model we projected where the additional 104 thousand hectares of palm oil would be located, what types of land cover would be impacted, and the extent of resulting peat soil drainage.

Table II-4 summarizes the projected locations of palm oil crops in Indonesia and Malaysia in 2022. Our analysis considers 45 different administrative units in Indonesia and Malaysia, but here the results are summarized into 5 aggregate regions. In the modeled scenario we project that close to 90% of the incremental palm oil expansion in Indonesia would occur in the Kalimantan region. This is consistent with UDSA's reporting that Kalimantan has been the fastest expanding region for palm oil over the last decade.[18] In Malaysia we project that most of the incremental palm oil expansion would occur on the mainland, i.e., Peninsular Malaysia. USDA reports that almost all of the highly suitable land for palm oil production has already been developed in Malaysia. According to USDA, Sarawak has the most remaining development potential, but the available areas on Sarawak are primarily coastal peatlands and/or degraded inland forest with native claims, [19] which makes these areas less desirable for cultivation due to complications arising from peat soil characteristics and land rights issues. Our modeling indicates that the most likely area for incremental expansion is on the mainland where existing plantations may be able to expand around the fringes in order to increase productive area.

[18] USDA-FAS (2009)
[19] USDA-FAS. 2011. Malaysia: Obstacles May Reduce Future Palm Oil Production Growth. Commodity Intelligence Report. June 28, 2011, http://www.pecad.fas.usda.gov/highlights/2011/06/Malaysia/

Table II-4. Projected Location of Palm Oil in Indonesia and Malaysia in 2022 (Thousand Harvested Hectares)

Country	Region	Control Case	Palm Biofuel Case	Difference
Indonesia	Kalimantan	1,396	1,452	56
	Sumatra	4,782	4,790	8
Malaysia	Peninsular Malaysia	3,016	3,048	32
	Sabah	1,351	1,357	6
	Sarawak	834	837	3

Following the lifecycle analysis methodology in RFS2 final rule, our analysis of land use change GHG emissions looks at the impacts associated with incremental expansion in harvested crop area in the scenarios analyzed. Typically palm oil is harvested for the first time 3-5 years after planting, followed by approximately 20-25 years of annual harvesting before the cycle is repeated.[20] This implies that in a steady state the ratio of immature (non-harvested) area to harvested area would be about 12-25%. Data published by MPOB shows that on average the ratio of immature to harvested area was 15% during the period from 1990 to 2009.[21]

Projecting the amount of palm oil area that would be immature in 2022 depends on several factors such as expansion and replanting rates which can vary over time and by

[20] Unnasch, S. S. T. Sanchez, and B. Riffel (2011) Well-to-Wheel GHG Emissions and Land Use Change Impacts of Biodiesel from Malaysian Palm Oil. Prepared for Malaysian Palm Oil Council. Life Cycle Associates Report LCA.6015.50P.2011.

[21] Department of Statistics, Malaysia. Table 1.2 Area Under Oil Palm Mature and Immature. MPOB Website, http://econ.mpob.gov.my/economy/annual/stat2009/Area1_2.pdf. Accessed December 2011

geographic region. For example, high palm oil prices may induce growers to continue harvesting their old plantations despite decreasing yields. This is because growers do not want to miss selling palm oil during a period of high prices while they are waiting for their replanted crops to mature. In fact, this is the current situation in Malaysia where many growers have delayed replanting to take advantage of high palm oil prices.[22] Furthermore, replanting rates could change based on technological developments. Currently, palm oil is replanted when it reaches 25 feet in height due to the length of the long sickle poles often used for harvesting.[23] The development of new clonal varieties and harvesting techniques could increase the economically viable lifetime of palm oil plantations, and thus reduce the ratio of immature to harvested area.

Accounting for the land use changes associated with expansion of immature as well as harvested areas of palm oil would be an additional source of land use change GHG emissions in our analysis. We invite comment on whether we should account for incremental expansion in the area of immature palm oil plantations in our analysis, and if so on which factors should be considered in making such a projection.

To evaluate land use change GHG emissions resulting from palm oil expansion we considered the soil and land cover types in the areas projected for conversion. Land cover types were determined based on MODIS satellite data, the same land cover data set that was used in the RFS2 final rule. According to our analysis, over the previous decade over 50% of palm oil has been grown on areas classified as forest in Indonesia,[24] and the figure is over 60% in

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[22] USDA-FAS (2011)
[23] Unnasch et al.
[24] Harris et al. (2011a), Table 9

Malaysia.[25] Table II-5 shows the projected types of land cover impacted in Indonesia and Malaysia by incremental palm oil expansion in 2022 in the scenarios modeled. We project that the forest and mixed land cover types would account for over 80% of the land cover impacted by palm oil expansion. (The mixed land cover category assumes equal shares of forest, grassland, shrubland and cropland.) These projections are in line with recent historical data,[26] USDA reports[27] and peer-reviewed literature,[28] which all indicate that much of the recent expansion in palm oil has been at the expense of tropical forest.

Table II-5. Projected Land Cover Types Impacted by Palm Oil Expansion in Indonesia and Malaysia in 2022

Land Cover Type	Indonesia	Malaysia
Forest	43%	54%
Mixed	38%	35%
Shrubland	0%	0%
Savanna	10%	1%
Grassland	1%	1%
Cropland	7%	5%
Wetland	1%	3%

[25] Harris et al. (2011b), Table 9
[26] Harris et al. (2011a) and (2011b)
[27] USDA-FAS (2009) and (2011)
[28] Koh, L. P., Miettinen, J., Liew, S. C. & Ghazoul, J. 2011. Remotely sensed evidence of tropical peatland conversion to oil palm. *Proceedings of the National Academy of Scientists of the United States of America,* 108, 5127-5132.

An even more critical factor in terms of estimating land use change GHGs in this region is the extent of tropical peat soil drained in order to prepare land for palm oil production. Almost all of the undisturbed tropical peat land in the world is located in Indonesia and Malaysia, with much smaller amounts also found in Philippines and Thailand.[29] Undisturbed tropical peat swamp forest removes carbon dioxide (CO_2) from the atmosphere and stores it in biomass and peat deposits. The incomplete decomposition of dead tree material under waterlogged, anaerobic conditions has led to slow accumulation of peat deposits over millennia, giving this ecosystem a very high carbon density. Typical estimates are that tropical peat soils sequester approximately 20 times more carbon than forest biomass on a per hectare basis.[30]

In their natural state, tropical peat lands are unfavorable for agricultural production compared to mineral soils, primarily because peat swamp has a ground water table that is at or close to the peat surface throughout the year. Despite these harsh conditions, peat swamps have recently been exploited to make room for agricultural and forest plantations as the global demand for food, wood and other resources has increased.[31] Some reasons that have been given for the recent development of peat swamps include that other suitable areas have already been used, advanced land conversion and drainage technologies have been developed, and in some cases seizing the swamps is less likely to result in native land disputes.[32] Koh et al. found that approximately 6% of tropical peatlands in Indonesia and Malaysia had been converted to palm

[29] Paramananthan, S. 2008. Tussle over Tropical Peatlands. *Global Oils & Fats: Business Magazine*. (5)3, 1-16
[30] Page, S. E., Morrison, R., Malins, C., Hooijer, A., Rieley, J. O. & Jauhiainen, J. 2011. *Review of peat surface greenhouse gas emissions from oil palm plantations in Southeast Asia* (ICCT White Paper 15). Washington: International Council on Clean Transportation.
[31] Hooijer, A., Page, S., Canadell, J. G., Silvius, M., Kwadijk, J., Wösten, H., & Jauhiainen, J. 2010. Current and future CO2 emissions from drained peatlands in Southeast Asia. *Biogeosciences,* 7, 1505-1514.
[32] Miettinen, J., Chenghua S., Liew, S., C. 2011. Two decades of destruction in Southeast Asia's peat swamp forests. *Frontiers in Ecology and the Environment*.

oil plantations by the early 2000s.[33] Based on our analysis of 2009 data we find that palm oil plantations have been developed disproportionately on peat soils, which occupy 13% of the total land area in Indonesia (Sumatra and Kalimantan) but host 25% of palm oil plantations.[34] For Malaysia, we estimate that in 2009 approximately 13% of palm oil plantations were on peat soils compared with only 8% of the country displaying that type of soil.[35] Table II-6 summarizes our analysis regarding the historical and projected extent of palm oil on tropical peat soil. The values in the last row, projected incremental expansion in 2022, are used in our analysis. Taking the weighted averages for Indonesia and Malaysia, based on the data in Table II-4 and Table II-6, we project that 11.5% of incremental palm oil expansion in 2022 will occur on tropical peat lands in the scenarios modeled.

Table II-6. Percent of Palm Oil Plantations on Peat Soil, Historical and Projected

Year	Indonesia	Malaysia
2009 (Historical)	22%	13%
2022 (Projected)	15%	10%
2022 (Projected Incremental Expansion)	13%	9%

Land use change emissions factors – In our analysis, GHG emissions per hectare of land conversion are determined using the emissions factors developed for the RFS2 final rule following IPCC guidelines.[36,37] In addition, several updates have been made to refine our land

[33] Koh et al. (2011)
[34] Harris et al. (2011a), Table 22
[35] Harris et al. (2011b), Table 19
[36]Harris, N., Brown, S., and Grimland, S. 2009a. Global GHG Emission Factors for Various Land-Use Transitions. Winrock International. Report Submitted to EPA. April 2009.
[37] Harris, N., Brown, S., and Grimland, S. 2009b. Land Use Change and Emission Factors: Updates since the RFS Proposed Rule. Winrock International. Report Submitted to EPA. December 2009

use change emissions factors for Indonesia and Malaysia. First, average above and below ground carbon stocks in palm oil plantations were revised based on new data. Second, GHG emissions associated with draining peat soils were updated according to new studies which consider data from hundreds of new field measurements. Finally, estimated average forest carbon stocks were updated based on a new study which uses a more robust and higher resolution analysis. In this section we briefly describe each of these updates. More information is available in a technical memorandum available through the docket.[38]

Palm Oil Carbon Stocks. In the final RFS2 rule, carbon stocks in palm oil plantations after one year of growth were estimated to be 15 tonnes carbon dioxide-equivalent per hectare (tCO_2e/ha). This was based on Table 5.3 of the 2006 IPCC Guidelines for Agriculture, Forestry and Other Land Use (AFOLU),[39] which gives biomass stocks on oil palm plantations as 136 tCO_2e/ha. The total carbon stock value reported by IPCC was divided by an assumed 15-year growth period to derive a linear growth rate. Our original analysis accounted for only one year of growth when estimating carbon storage on palm oil plantations.

We have revised our analysis of palm oil carbon stocks in favor of a more accurate time-averaged approach, using average carbon stocks over the life of the plantation. Since a typical rotation period for palm oil is approximately 30 years (e.g., 3-5 years as immature plus 20-25 years of harvesting), this approach is more appropriate for our lifecycle analysis methodology as established in the RFS2 final rule, which considers land use change emissions over a 30-year

[38] Harris, N. 2011. Revisions to Winrock's Land Conversion Emission Factors since the RFS2 Final Rule. Winrock International report to EPA.
[39] 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use. Chapter 5. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

period. A literature review of palm oil carbon stocks was conducted, and based on this review we modified the carbon stocks of palm oil plantations to a time-averaged value of 128 tCO_2e/ha.[40]

Peat Soil Emissions Factors. Development of tropical peatland for palm oil production requires removal of the vegetative cover and typical drainage depths of 0.6 to greater than 1.0 meter. Drainage is accomplished by construction of a network of deep canals and shallower ditches. Additionally, the peat surface is often compacted by the weight of heavy vehicles to improve its load-bearing characteristics and increase the stability of palm trees. These changes remove carbon from the peatland system by lowering the peat water table, ensuring continuous aerobic decomposition of organic material and greatly reducing preservation of new carbon inputs to the peat from biomass. As a result the peat swamp ecosystem switches from a net carbon sink to a large source of carbon emissions. On completion of a productive palm oil cycle, the plantation is typically renewed by land clearance, drainage and replanting.[41]

In the RFS2 final rule peat soil emissions in Indonesia and Malaysia were estimated based on a relationship developed by Hooijer et al. (2006) that correlates peat drainage depth with annual peat CO2 emissions.[42] Assuming average drainage depth of 0.8 meters, average emissions from drained peat soils were estimated to be 73 tCO_2 per hectare per year.

For our palm oil analysis average peat soil emissions have been updated based on a

[40] Harris (2011)
[41] Page et al.
[42] Hooijer, A., M. Silvius, H. Wösten and S. Page. 2006. PEAT-CO2, Assessment of CO2 emissions from drained peatlands in SE Asia. Delft Hydraulics report Q3943.

newly available study (Hooijer et al. 2011)[43] which considers over 200 subsidence measurements (more than were previously available for all peatlands in Southeast Asia combined), taken at various locations including palm oil and acacia plantations on peat soil.[44] Earlier studies had assumed constant annual emissions over time following peat soil drainage. Hooijer et al. (2011) is the only source with enough data to calculate peat carbon emissions over various time scales. These data showed higher rates of emission in the years immediately following drainage. As such, average annual emissions are no longer derived as a function of drainage depth but are instead based on the time scale of analysis. Based on Hooijer et al. (2011), our analysis assumes that average emissions from peat soil drainage are 95 tCO2e/ha/yr over a 30-year time period. This is supported by Page et al., who reviewed studies of carbon emissions from peat drainage and concluded that this is the most robust estimate of emissions over a 30-year period. They noted that this estimate, which is based on subsidence measurements, closely matches estimates from similar recent studies which use other measurement techniques such as direct gas fluxes.[45]

Forest Carbon Stocks. For the RFS2 final rule, international forest carbon stocks were estimated from several data sources each derived using a different methodological approach. Two new analyses on forest carbon stock estimation were completed since the release of the final RFS2 rule, one for three continental regions by Saatchi et al.[46] and the other for the EU by

[43] Hooijer, A., Page, S. E., Jauhiainen, J., Lee, W. A., Idris, A., & Anshari, G. 2011. Subsidence and carbon loss in drained tropical peatlands: reducing uncertainty and implications for CO2 emission reduction options. *Biogeosciences Discussions*, 8, 9311-9356

[44] Page et al., 53

[45] Jauhiainen, J., Hooijer, A., & Page, S. E. (2011). Carbon Dioxide Fluxes in an Acacia Plantation on Tropical Peatland. Biogeosciences Discussions, 8, 8269-8302.

[46] Saatchi, S.S., Harris, N.L., Brown, S., Lefsky, M., Mitchard, E.T.A., Salas, W., Zutta, B.R., Buermann, W., Lewis, S.L., Hagen, S., Petrova, S., White, L., Silman, M. And Morel, A. 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. *PNAS* doi: 10.1073/pnas.1019576108.

Gallaun et al.[47] We have updated our estimates based on these new studies because they represent significant improvements as compared to the data used in the RFS2 rule. Forest carbon stocks across the tropics are particularly important in our analysis of palm oil biofuels because palm oil is grown in tropical regions. In the scenarios modeled there are also much smaller amounts of land use change impacts in the EU related to palm oil biofuel production. As such, we took this opportunity to incorporate the improved forest carbon stocks data in both of these regions.

Preliminary results for Latin America and Africa from Saatchi et al. were incorporated into the final RFS2 rule, but Asia results were not included due to timing considerations. The Saatchi et al. analysis is now complete, and so the final map was used to calculate updated area-weighted average forest carbon stocks for the entire area covered by the analysis (Latin America, sub-Saharan Africa and South and Southeast Asia). The Saatchi et al. results represent a significant improvement over previous estimates because they incorporate data from more than 4,000 ground inventory plots, about 150,000 biomass values estimated from forest heights measured by space-borne light detection and ranging (LIDAR), and a suite of optical and radar satellite imagery products. Estimates are spatially refined at 1-km grid cell resolution and are directly comparable across countries and regions.

In the final RFS2 rule, forest carbon stocks for the EU were estimated using a combination of data from three different sources. Issues with this ‘patchwork’ approach were that the biomass estimates were not comparable across countries due to the differences in

[47] Gallaun, H., Zanchi, G., Nabuurs, G.J., Hengeveld, G., Schardt, M., Verkerk, P.J. 2010. EU-wide maps of growing stock and above-ground biomass in forests based on remote sensing and field measurements. *Forest Ecology and Management* 260: 252-261.

methodological approaches, and that estimates were not spatially derived (or, the spatial data were not provided to EPA). Since the release of the final rule, Gallaun et al. developed EU-wide maps of above-ground biomass in forests based on remote sensing and field measurements. MODIS data were used for the classification, and comprehensive field measurement data from national forest inventories for nearly 100,000 locations from 16 countries were also used to develop the final map. The map covers the whole European Union, the European Free Trade Association countries, the Balkans, Belarus, the Ukraine, Moldova, Armenia, Azerbaijan, Georgia and Turkey.

For both data sources, Saatchi et al. and Gallaun et al., we added belowground biomass to reported aboveground biomass values using an equation in Mokany et al.[48] More details regarding updated forest carbon stock estimates are available in a technical report to the docket.[49]

In our analysis, forest stocks are estimated for over 750 regions across 160 countries. For some regions the carbon stocks increased as a result of the updates and in others they declined. For comparison, we ran our palm oil analysis using the old forest carbon stock values used in the RFS2 rule and with the updated forest carbon values described above. Using the updated forest carbon stocks decreased the land use change GHG emissions related to palm oil biofuels by only 0.1%.

Harvested Wood Products. Another update that was incorporated into our analysis of Indonesia and Malaysia is related to harvested wood products (HWP). When forest is cleared a

[48] Mokany, K., R.J. Raison, and A.S. Prokushkin. 2006. Critical analysis of root:shoot ratios in terrestrial biomes. Global Change Biology 12: 84-96.
[49] Harris (2011)

fraction of the vegetation is harvested as valuable timber for use in wood products such as sawn wood, wood panels, paper and paperboard. Accounting for HWP in our analysis involves estimating the amount of carbon that is sequestered in these wood products for at least the length of the analysis period (i.e., greater than 30 years). For the final RFS2 rule we addressed the potential significance of the HWP pool and concluded that for most regions of the world the amount of carbon stored in wood products long-term was insignificant, especially when considering a timeframe of 30 years. Therefore, carbon storage in HWP was not incorporated into the emission factors for deforestation in the RFS2 final rule.

For this analysis we have estimated carbon storage in HWP for timber extraction in Indonesia and Malaysia. Our updated assessment is based on the approved Verified Carbon Standard methodology for estimation of carbon stocks in the long-term wood products pool.[50] We undertook this update because based on our analysis Indonesia and Malaysia have the highest average timber extraction rates in the world, equaling 52 and 42 cubic meters per hectare (m^3/ha), respectively.[51] The fraction of extracted biomass that ends up as wood waste during production was estimated as a constant 19% based on Winjum et al.[52] We also estimated the fraction of wood products which will be retired and oxidized to the atmosphere in 30 years or less after harvesting. After accounting for wood waste and carbon in products that will not last for more than 30 years, the remainder is assumed to be the carbon stored in HWP after 30 years. We estimate that on average the carbon stored in harvested wood products after 30 years equals 3.0 and 1.9 tonnes of carbon per hectare of forest cleared (tC/ha) in Indonesia and Malaysia,

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[50] Verified Carbon Standard (VCS) methodology module VMD0005: Estimation of carbon stocks in the long-term wood products pool (CP-W), Sectoral Scope 14, http://www.v-c-s.org/methodologies/find
[51] Only two other countries have extraction rates above 20 m^3/ha: India with 33 m^3/ha and China with 22 m^3/ha.
[52] Winjum, J.K., Brown, S., Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284.

respectively. These values are quite small compared to the forest carbon stocks in the region, which are typically in the range of 150-200 tC/ha. For more details on our updated assessment of HWP refer to the technical report available through the docket.[53]

Land use change emissions results – Based on the analysis described above we estimated land use change GHG emissions related to the production and use of biodiesel and renewable diesel from palm oil feedstock. Most of the land use change emissions associated with these two biofuels occur in Indonesia and Malaysia. Table II-7 includes the land use change GHG emissions results for the scenarios modeled, in terms of million metric tonnes of carbon-dioxide equivalent over 30 years (MMT CO_2e/yr over 30 yrs). These are the incremental emissions related to the production and use of approximately 400 million additional gallons of palm oil biofuels in the palm biofuel case compared to the control case. For Indonesia and Malaysia the emissions are broken out by land conversion category, showing that the dominant sources of emissions are from peat swamp drainage and forest clearing in these two countries.

Table II-7. Land Use Change GHG Emissions (MMT CO_2e/yr over 30 yrs)

Source of Emissions	Indonesia	Malaysia	Rest of World
Forest Clearing	0.33	0.46	NA
Other Land Cover Clearing	(0.02)	0.03	
Peat Soil Drainage	0.81	0.33	
Total	1.11	0.83	0.37

[53] Harris (2011)

5. Analysis of Palm Oil Mills

A key part of our analysis focuses on palm oil mills where bunches of fresh palm fruit are separated into palm kernels, empty fruit bunches, and the remaining fruit which contains crude palm oil. This is a similar step to soybean crushing which is included in the soybean biodiesel lifecycle analysis in the RFS2 rule. EPA's analysis for palm oil mills includes an assessment of the energy and materials flows for an average palm oil mill and the resulting lifecycle GHG emissions.

Palm oil mills extract crude palm oil using steam for sterilization, mechanical stirring, screw presses and other filtering, purifying and drying processes. The main solid wastes from the process (i.e., empty fruit bunches, mesocarp fiber, shells) are commonly returned to the field as fertilizer or used as fuel to generate steam and electricity for use in the mill. The main liquid waste called palm oil mill effluent (POME) is a dark brown slurry containing waste water, plant oil, and debris from the palm fruit. To meet environmental standards for discharge into local waterways the POME is treated in a series of anaerobic lagoons or tanks. When the POME is digested it generates biogas containing various concentrations of carbon dioxide and methane. If POME is digested in open ponds or tanks, the methane and carbon dioxide is emitted to the atmosphere. Our analysis indicates that the methane emissions from POME digestion can represent a substantial portion of the lifecycle GHG emissions associated with palm oil biodiesel. However, if covered lagoons or closed digester tanks are used, at least some of this methane can be captured and then either flared or used to generate electricity and/or steam. This process converts methane, which has a high global warming potential (GWP) of 21, to CO_2 , which has a lower GWP of 1, thus preventing the higher impact methane from entering the atmosphere.

Because POME methane emissions are an important part of the lifecycle GHG emissions associated with palm oil biofuels, we collected information specifically looking at the deployment of POME methane capture/use technologies at palm oil mills. According to a mandatory survey of 422 Malaysian palm oil mills conducted by the Malaysian Palm Oil Board in 2010, 38 mills were capturing POME biogas, 34 mills had POME biogas capture projects under construction, and 47 mills were in various stages of planning to implement biogas capture at some point between 2012 and 2020. Among the mills that are currently capturing POME biogas, 63% use closed tank digesters and 37% use covered lagoons. Forty percent of the mills that are capturing POME biogas destroy it with flaring, 34% use it to generate electricity, 5% use it to produce steam, and 21% employ combined heat and power to generate steam and electricity.

Information about POME methane capture was also provided by the Indonesian Embassy. According to the information provided, 3.5% of Indonesia's 608 palm oil mills are currently capturing POME biogas with an additional 2% of the mills in the process of constructing biogas capture/use projects. Thus, we estimate that 33 of Indonesia's 608 mills have methane capture/use projects in operation or under construction. All of the mills that currently capture POME biogas have covered lagoons and use the captured methane to generate electricity, based on data provided by the Indonesian Embassy.

We are using the data from the Malaysian survey of palm oil mills and the information provided by the Indonesian Embassy to derive the industry average used in our lifecycle analysis. Based on the information collected and described above, our assessment of the lifecycle GHG emissions from industry average palm oil mills assumes that 10% of palm oil mills capture the methane from anaerobic digestion of POME (i.e., 105 mills capture methane out of 1,030 total mills in Indonesia and Malaysia). Of the mills that capture POME methane we assume, based on the data described above, that 27% of the mills flare captured methane, 55% use the methane for electricity generation, 3% use the methane to produce steam and 14% use the methane to produce electricity and steam (the percentages do not sum to 100% due to rounding). We believe that deriving the industry average in this manner is reasonable because palm oil mills in Malaysia and Indonesia represent close to 90% of crude palm oil production, and we do not have any reason to believe that biogas capture rates would be different enough in the other palm oil producing regions to affect our determinations.

As discussed above, our analysis is based on average practices at palm oil mills in Indonesia and Malaysia. This is because the vast majority of palm oil for biofuel production would be extracted in these two countries. If the portion of facilities capturing biogas outside of Malaysia and Indonesia is different than currently within Malaysia and Indonesia or if the methane capture/use efficiencies are different than assumed in our analysis, then the average GHG emissions from palm mill operations would be different and the overall GHG performance of the biofuels produced from palm oil would be different than determined in our analysis. Because the vast majority of palm oil biofuel production is likely to occur in Indonesia and Malaysia, the impact of these differences on our results would be minimized because our analysis looks at average palm oil production practices.

For this analysis, we determined the percentage of facilities employing methane capture /use based on projects currently in operation or under construction (facilities in the planning stage are not included). The analysis does not include any projected increases in the number of facilities that will employ these technologies above and beyond those currently operating or being installed between now and 2022. We do not project an increase because we are not aware of a technical or economic basis for making such a projection. For example, we do not have a sufficient technical or economic basis for determining how many of the mills in Malaysia that are at some stage of planning methane capture and use projects will actually follow through with construction and operation. For Indonesia and other countries we have even less information about additional possible deployment of such projects. Methane capture and use as applied to palm oil mills is a relatively new technology which has not been widely adopted (i.e., 10% of mills are currently using this technology in Indonesia and Malaysia). At this time, adoption of methane capture and use technology is entirely done voluntarily; there are no laws requiring its deployment.

There are no mandatory requirements to install methane capture and use technologies, and no other strong reasons on which to base a projection of increased adoption of these technologies. Methane capture and use involves clear and significant costs, both in terms of equipment purchase and installation as well as in routine maintenance. If the captured methane is flared, the only option for a facility to recoup a portion of its costs would be through some type of certified emission reduction credit program, such as through the CDM.[54] Certification under the CDM, though, requires additional time and costs and after more than a decade of operation

[54] For more information about the Clean Development Mechanism, which is implemented under the United Nations Framework Convention on Climate Change, refer to: http://cdm.unfccc.int/

the incentives provided by the CDM have spurred limited adoption of biogas capture at palm oil mills, as evidenced by the data on adoption of methane capture and use technologies at palm oil mills in Malaysia and Indonesia discussed above.

We recognize that in some cases, it may make economic sense to, at additional cost, install equipment for using the methane as a fuel to generate electricity. Currently, palm oil mills in remote areas which do not have access to grid electricity tend to burn waste palm material to generate necessary process energy. EPA does not have sufficient information on which to determine how many facilities will, for economic reasons, choose to replace current equipment using the burning of waste palm material with methane capture and electricity generation capacity.

This lack of information and basis for projecting the increased use of methane capture and use contrasts to other cases where, in the context of performing lifecycle GHG emissions analysis for the RFS program, we have been able to project technology improvements through 2022. For example, we have many years of data demonstrating a gradual increase in crop yields per acre for palm oil. Additionally, we know that substantial research continues in further improvements to palm oil yields and that as new varieties of oil palm come on market farmers have a natural economic incentive to adopt the enhanced crop varieties. We are thus able to project with a reasonably high degree of confidence a rate of continued improvement in palm oil crop yield through 2022. By contrast, we determined that biodiesel production technologies are mature and therefore we do not predict any improvements in process technology. In sum, where we have had sufficient information to predict improvements in the general state of technology across the industry, we have done so, but where no such basis exists—such as for methane capture/use at palm oil mills—we do not include such projections in our analysis.[55]

At least some methane capture/use projects at palm oil mills in Malaysia and Indonesia are registered under the CDM, but our analysis does not treat emission reductions differently based on whether or not a palm oil mill's methane capture/use project is CDM-registered. As defined in Article 12 of the Kyoto Protocol, the CDM allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement emission-reduction projects in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets. For example, CERs can be used for compliance purposes under the European Union's (EU) Emissions Trading System (ETS). A CER from a palm oil methane destruction project in Malaysia, for example, could conceivably be used for compliance under the EU ETS. Under such a scenario, an argument could be made that counting the emission reductions from a "retired" CER as part of our lifecycle analysis would effectively be double counting the same emission reduction. While CDM's project database states that 47 palm oil mills in Indonesia and Malaysia have methane capture/use projects registered with the CDM,[56,57] we have been unable to verify that any CERs generated by methane capture/use at the relevant

[55] We note, however, that, based on our analysis, our proposed determinations regarding lifecycle GHG thresholds would not change even if we assumed that all of the methane capture projects being planned in Malaysia will come to fruition. See Section II.D.2 for more information.
[56] Using the website: http://cdm.unfccc.int/Projects/projsearch.html; six project title searches were completed with the keywords "palm", "POME", "wastewater", "waste water", "biogas", and "methane." Search results were then examined to determine which projects involved methane capture from anaerobic digestion of POME.
[57] These 47 mills represent approximately 79% of the mills with operational methane capture and use projects, but only about 5% of all mills in Indonesia and Malaysia

palm oil mills have actually been used to meet obligations under the EU ETS.[58] However, even if all of the available CER credits for methane emissions reduction had been purchased and retired for compliance purposes (and were thus not counted in our analysis), this would increase our lifecycle GHG emission estimates by a only a relatively small amount (on the order of 2%). A final factor informing our approach on this topic is uncertainty about whether the CDM and ETS programs will be extended in their current form. Based on our lack of evidence that relevant CERs had been purchased, the relative magnitude of the emissions in question, and general uncertainty about the future of the CDM and ETS programs, our approach for lifecycle analysis purposes is to treat emission reductions from CDM-registered palm oil projects as we treat any other emission reduction. While we believe we do not have a strong technical or economic basis treating them otherwise at this time, we ask for further comment on this topic.

According to the MPOB, another potential practice that can avoid methane emissions from palm oil mills entails recovering the organic solids from POME so that there is no anaerobic digestion and therefore no methane emissions.[59] Unless the recovered solids are used to replace other products the GHG reduction benefits of this technology are likely to be less than reductions associated with methane capture/use for electricity generation. MPOB data suggests that methane avoidance has not been deployed at a significant number of palm oil mills. Because we do not have a strong technical or economic basis for projecting the deployment of this technology it is not considered in our lifecycle analysis.

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[58] Cross-checking the registered mills with an EC list of CERs surrendered under the EU ETS as of March 19, 2010 yielded no matches. Unfortunately, due to the design of their electronic databases, the European Commission was unable to verify for us whether any of the CERs generated by methane capture at palm oil mills have been purchased and used by European companies. Personal communication with Thomas Bernheim (European Commission) from September 23, 2011.

[59] MPOB (2010)

Our analysis also accounts for the co-products from palm oil mills. We assume that the biomass co-products (e.g., mesocarp fiber and shells) are used for heat and energy, with remaining empty fruit bunches trucked back to the field for use as fertilizer. We also account for the palm kernel co-product and model the emissions related to transporting the palm kernels to a separate milling facility where palm kernel oil and palm kernel meal are produced. Our agricultural modeling accounts for the use of the palm kernel oil and meal in the food and feed markets.

The docket includes a memorandum with more discussion of and justification for the data, inputs and assumptions used in our analysis of palm oil mills.[60] EPA invites comment on all aspects of its modeling of lifecycle GHG emissions from palm oil mills, including all of the assumptions and data inputs used.

B. Results of Lifecycle Analysis for Biodiesel from Palm Oil

We analyzed the lifecycle GHG emission impacts of producing biodiesel using palm oil as a feedstock assuming the same biodiesel production facility designs and conversion efficiencies as modeled in RFS2 for biodiesel produced from soybean oil. Our analysis looks at biodiesel produced in Indonesia or Malaysia which is then shipped to the United States via ocean tanker. As such, GHG emissions associated with electricity used at biodiesel production facilities were determined based on the emissions factors for grid average electricity generation in Indonesia and Malaysia.

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[60] EPA (2011)

As was the case for soybean oil biodiesel, production technology for palm oil biodiesel is mature and we have not projected in our assessment of palm oil biodiesel any significant improvements in plant technology; while unanticipated energy saving improvements would tend to improve GHG performance of the fuel pathway, there is no valid basis for projecting such improvements. Additionally, similar to soybean oil biodiesel production, we assumed that the co-product glycerin would displace residual oil as a fuel source on an energy equivalent basis.

As part of the RFS2 proposal we assumed the glycerin would have no value and would effectively receive no co-product credits in the soy biodiesel pathway. We received numerous comments, however, as part of the RFS2 final rule stating that the glycerin would have a beneficial use and should generate co-product benefits. Therefore, the biodiesel glycerin co-product determination made as part of the RFS2 final rule took into consideration the possible range of co-product credit results. The actual co-product benefit will be based on what products are replaced by the glycerin, or what new uses the co-product glycerin is applied to. The total amount of glycerin produced from the biodiesel industry will actually be used across a number of different markets with different GHG impacts. This could include for example, replacing petroleum glycerin, replacing fuel products (residual oil, diesel fuel, natural gas, etc.), or being used in new products that don't have a direct replacement, but may nevertheless have indirect effects on the extent to which existing competing products are used. The more immediate GHG reductions from glycerin co-product use will likely range from fairly high reductions when petroleum glycerin is replaced to lower reduction credits if it is used in new markets that have no direct replacement product, and therefore no replaced emissions. EPA does not have sufficient information (and received no relevant comments to the RFS2 proposal) on which to allocate glycerin use across the range of likely uses. EPA's approach is to pick a surrogate use for modeling purposes in the mid-range of likely glycerin uses, and focus on the more immediate GHG emissions results tied to such use. The replacement of an energy equivalent amount of residual oil is a simplifying assumption determined by EPA to reflect the mid-range of possible glycerin uses in terms of GHG credits, and EPA believes that it is appropriately representative of GHG reduction credit across the possible range without necessarily biasing the results toward high or low GHG impact. Given the fundamental difficulty of predicting possible glycerin uses and impacts of those uses many years into the future under different market conditions, EPA believes it is reasonable to use its more simplified approach to calculating co-product GHG benefit associated with glycerin production. To narrow this area of uncertainty in our analysis we invite commenters to submit data regarding the use of glycerin produced at biodiesel production facilities, and especially for glycerin produced at facilities that are based in Indonesia or Malaysia or that use palm oil as a feedstock.

As with other EPA analyses of fuel pathways with a significant land use impact, our analysis for palm oil biodiesel includes a mid-point estimate as well as a range of possible lifecycle GHG emission results based on uncertainty analysis conducted by the Agency. The graph included below (Figure II-1) depicts the results of our analysis (including the uncertainty in our land use change modeling) for palm oil biodiesel produced via trans-esterification using natural gas as process energy, because this is the primary source of process energy at existing plants. The docket also includes pathway analyses assuming coal or biomass is used instead of natural gas for process energy. Because the trans-esterification process requires a relatively small amount of energy, our threshold determinat ions would remain the same for the palm oil biodiesel pathway regardless of whether natural gas, coal or biomass is used for energy in the biodiesel production process.

Figure II-1 shows the results of our biodiesel modeling. It shows the percent difference between lifecycle GHG emissions for the modeled 2022 palm oil biodiesel, produced via trans-esterification using natural gas for process energy, and those for the petroleum diesel fuel 2005 baseline. Lifecycle GHG emissions equivalent to the statutory diesel fuel baseline are represented on the graph by the zero on the X-axis. The results for palm oil biodiesel are that the midpoint of the range of results is a 17% reduction in GHG emissions compared to the 2005 diesel fuel baseline.[61] As in the case of other biofuel pathways analyzed as part of the RFS2 rule, the range of results shown in Figure II-1 is based on our assessment of uncertainty regarding the location and types of land that may be impacted as well as the GHG impacts associated with these land use changes (See Section II.D.3. for further information). These results, if finalized, would justify our determination that fuel produced by the modeled palm oil biodiesel pathway fails to meet the 20% reduction threshold required for the generation of conventional renewable fuel RINs.

[61] The 95% confidence interval around that midpoint results in range of a 4% increase to a 35% reduction compared to the 2005 diesel fuel baseline.

Figure II-1. Distribution of Results for Palm Oil Biodiesel Produced Via Transesterification with Natural Gas for Process Energy

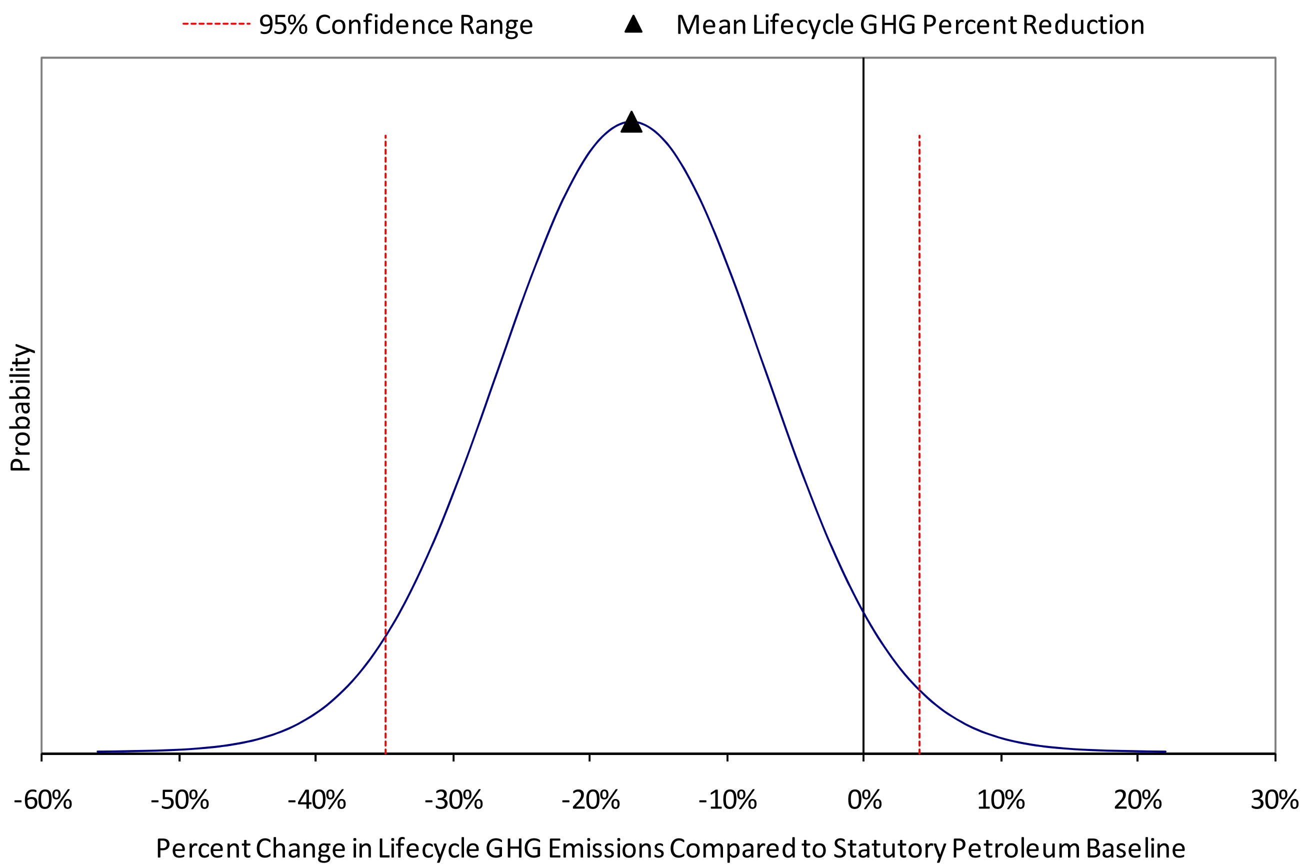

Table II-8 breaks down by stage the lifecycle GHG emissions for palm oil biodiesel in 2022 and the statutory 2005 diesel baseline.[62] Results are included using our mid-point estimate of land use change emissions, as well as with the low and high end of the 95% confidence interval. Net agricultural emissions include impacts related to changes in crop inputs, such as fertilizer, energy used in agriculture, livestock production and other agricultural changes in the

[62] Totals in the table may not sum due to rounding.

scenarios modeled. Land use change emissions are discussed above in Section II.A.4. Emissions from fuel production include emissions from palm oil mills, palm kernel mills and the trans-esterification process to produce biodiesel. Fuel and feedstock transport includes emissions from transporting fresh fruit bunches, palm kernels, crude palm oil and finished biodiesel along each stage of the lifecycle. In our analysis we assume that palm oil is converted to biodiesel in Indonesia and Malaysia and then the biodiesel is transported via ocean tanker to the U.S. Transporting crude palm oil to the U.S. would result in greater GHG emissions because biodiesel has greater energy density than crude palm oil.

Table II-8. Lifecycle GHG Emissions for Palm Oil Biodiesel (kgCO_2e / mmBtu)

Fuel Type	Palm Oil Biodiesel	2005 Diesel Baseline
Net Agriculture (w/o land use change)	5	
Land Use Change, Mean *(Low/High)*	46 *(28/66)*	
Fuel Production	25	18
Fuel and Feedstock Transport	4	*
Tailpipe Emissions	1	79
Total Emissions, Mean *(Low/High)*	**80 *(62/101)***	**97**
Midpoint Lifecycle GHG Percent Reduction Compared to Petroleum Baseline	**17%**	

*Emissions included in fuel production stage.

The docket for this NODA provides more details on our key model inputs and assumptions, e.g., crop yields, biofuel conversion yields, and agricultural energy use. These inputs and assumptions are based on our analysis of peer-reviewed literature and consideration of recommendations of experts from within the palm oil and biodiesel industries and those from USDA as well as the experts at Iowa State University who have designed the FAPRI-CARD models. EPA invites comment on all aspects of its modeling of palm oil biodiesel, including all assumptions made and modeling inputs.

C. Results of Lifecycle Analysis for Renewable Diesel from Palm Oil

Palm oil can also be used in a hydrotreating process to produce a slate of products, including diesel fuel, heating oil (defined as No. 1 or No. 2 diesel), jet fuel, naphtha, liquefied petroleum gas (LPG), and propane. Since the RFS regulations define the term renewable diesel to include the products diesel fuel, jet fuel and heating oil (40 CFR 80.1401), the following discussion uses the term renewable diesel to refer to all of these products. (The terms diesel fuel or diesel fuel replacement are used to refer to only the diesel fraction of the hydrotreating output.) While any propane (also referred to as fuel gas) produced as part of the hydrotreating process will most likely be combusted within the facility for process energy, the other co-products that can be produced (i.e., jet fuel, naphtha, LPG) are higher value products that could be used as transportation fuels or, in the case of naphtha, a blendstock for production of transportation fuel. The hydrotreating process maximized for producing a diesel fuel replacement as the primary fuel product requires more overall material and energy inputs than transesterification to produce biodiesel, but it also results in a greater amount of other valuable co-products, as listed above. The hydrotreating process can also be maximized for jet fuel production which requires even more process energy than the process optimized for producing a diesel fuel replacement and produces a greater amount of co-products per barrel of feedstock, especially naphtha.

Our lifecycle analysis accounts for the various uses of the co-products from hydrotreating. There are two main approaches to accounting for the co-products produced, the allocation approach and the displacement approach. In the allocation approach all the emissions from the hydrotreating process are allocated across all the different co-products. There are a number of ways to do this, but since the main use of the co-products would be as fuel products, we allocate based on the energy content of the co-products produced. So emissions from the process would be allocated equally to all the Btus produced. Therefore, on a per Btu basis all co-products would have the same emissions. The displacement approach would attribute all of the emissions of the hydrotreating process to one main product and then account for the emission reductions from the other co-products displacing alternative products. So for example, if the hydrotreating process is configured to maximize renewable diesel production all of the emissions from the process would be attributed to renewable diesel, but we would then assume the other co-products were displacing alternative products, for example, naphtha would displace gasoline, LPG would displace natural gas, etc. This assumes the other alternative products are not produced or used so we would subtract the emissions of gasoline production and use, natural gas production and use, etc. This would show up as a GHG emission credit associated with the production of the renewable diesel.

To account for a hypothetical scenario where RINs are generated from the renewable jet fuel, heating oil, naphtha and LPG in addition to the diesel replacement fuel produced, we would not give the diesel replacement fuel a displacement credit for these co-products. Instead, the lifecycle GHG emissions from the fuel production processes would be allocated to each of the RIN-generating products on an energy content basis. This has the effect of tending to increase the fuel production lifecycle GHG emissions associated with the diesel replacement fuel because there are fewer co-product displacement credits to assign than would be the case if RINs were not generated for the co-products.[63] On the other hand, the upstream lifecycle GHG emissions associated with producing and transporting the plant oil feedstocks will be distributed over a larger group of RIN-generating products. Assuming each product (except propane) produced via the palm oil hydrotreating process would generate RINs results in higher lifecycle GHG emissions for diesel fuel replacement as compared to the case where the co-products are not used to generate RINs. This general principle is also true when the hydrotreating process is maximized for jet fuel production. As a result, the best GHG performance (i.e., least lifecycle GHG emissions) for palm-oil renewable diesel via hydrotreating will occur when none of the co-products are RIN-generating (i.e., only the diesel replacement fuel is use to generate RINs).

We have evaluated information about the lifecycle GHG emissions associated with the hydrotreating process which can be maximized for renewable jet fuel or diesel production. Our evaluation considers information published in peer-reviewed journal articles and publicly available literature (Kalnes et al.,[64] Pearlson, [65] Stratton et al., Huo et al. [66]). Our analysis of

[63] For a similar discussion see Stratton R. W., Wong, H., M., Hileman, J., I. 2011. Quantifying Variability in Lifecycle Greenhouse Gas Inventories of Alternative Middle Distillate Transportation Fuels. *Environmental Science & Technology*. 45, 4640

[64] Kalnes, T., N., McCall, M., M., Shonnard, D., R., 2010. Renewable Diesel and Jet-Fuel Production from Fats and Oils. Thermochemical Conversion of Biomass to Liquid Fuels and Chemicals, Chapter 18, p. 475

[65] Pearlson, M., N. 2011. A Techno-Economic and Environmental Assessment of Hydroprocessed Renewable Distillate Fuels. http://dspace.mit.edu/handle/1721.1/65508

GHG emissions from the hydrotreating process is based on the mass and energy balance data in Pearlson which analyzes a hydrotreating process maximized for diesel production and a hydrotreating process maximized for jet fuel production.[67] These data are summarized in Table II-9.[68]

Table II-9. Hydrotreating Process to Produce Renewable Diesel Fuel

	Maximized for Diesel Fuel Production	Maximized for Jet Fuel Production	Units (per gallon of fuel produced)
Inputs			
Crude Palm Oil	9.56	12.84	Lbs
Hydrogen	0.04	0.08	Lbs
Electricity	652	865	Btu
Natural Gas	23,247	38,519	Btu
Outputs			
Diesel Fuel	123,136	55,845	Btu
Jet Fuel	23,197	118,669	Btu
Naphtha	3,306	17,042	Btu
LPG	3,084	15,528	Btu
Propane	7,454	9,881	Btu

[66] Huo, H., Wang., M., Bloyd, C., Putsche, V., 2008. Life-Cycle Assessment of Energy and Greenhouse Gas Effects of Soybean-Derived Biodiesel and Renewable Fuels. Argonne National Laboratory. Energy Systems Division. ANL/ESD/08-2. March 12, 2008

[67] We have also considered data submitted by companies involved in the hydrotreating industry which is claimed as confidential business information (CBI). The conclusions using the CBI data are consistent with the analysis presented here.

[68] Based on Pearlson, Table 3.1 and Table 3.2

Table II-10 compares lifecycle GHG emissions from hydrotreating for palm-oil-based renewable diesel and jet fuel. The lifecycle GHG estimates for palm-oil diesel and jet fuel are based on the input/output data summarized in Table II-9. For the scenarios analyzed, we assume that the LPG and propane co-products do not generate RINs; instead, they are used for process energy displacing natural gas. We also assume that the naphtha does not generate RINs but is used as blendstock for production of transportation fuel displacing conventional gasoline. As discussed above, lifecycle GHG emissions per Btu of diesel or jet fuel would be higher if the naphtha or LPG were used to generate RINs.

Table II-10. Hydrotreating Lifecycle GHG Emissions ($gCO_2e/mmBtu$)

<table>
<tr><td>Process</td><td>RIN-Generating Products</td><td>Other Co-Products</td><td>Hydrotreating Emissions</td></tr>
<tr><td rowspan="3">Hydrotreating Maximized for Diesel</td><td>Diesel</td><td>Naphtha</td><td rowspan="3">4,448</td></tr>
<tr><td rowspan="2">Jet Fuel</td><td>LPG</td></tr>
<tr><td>Propane</td></tr>
<tr><td rowspan="3">Hydrotreating Maximized for Jet Fuel</td><td>Diesel</td><td>Naphtha</td><td rowspan="3">(3,358)</td></tr>
<tr><td rowspan="2">Jet Fuel</td><td>LPG</td></tr>
<tr><td>Propane</td></tr>
</table>

In Table II-10 the process maximized for jet fuel production results in negative emissions at the hydrotreating stage. This is due to the displacement credits for co-products, especially naphtha, replacing conventional gasoline.[69] As shown in Table II-9, the process maximized for jet fuel production requires significantly more crude palm oil per Btu of fuel output. Each additional pound of palm oil used in the process has related lifecycle GHG emissions associated with producing, processing and transporting the palm oil to the hydrotreating facility. As a

[69] Co-product displacement accounting is described further in the inputs and assumptions document available through the public docket for this notice.

result, when palm oil is used as the feedstock, the full lifecycle GHG emissions are greater for the process maximized for jet fuel when all of the stages of the lifecycle are factored into the analysis. Unless otherwise noted, the analysis of palm oil renewable diesel in this preamble refers to the first scenario in Table II-10: hydrotreating maximized for production of diesel fuel replacement. Supporting information for the values in Table II-10 is provided through the docket.

As discussed above, for a process that produces more than one RIN-generating output we allocate lifecycle GHG emissions to the RIN-generating products on an energy equivalent basis. We then normalize the allocated lifecycle GHG emissions per mmBtu of each fuel product. Therefore, each RIN-generating product from the same process will be assigned equal lifecycle GHG emissions per mmBtu from fuel processing. For example, based on the lifecycle GHG estimates in Table II-10, for the hydrotreating process maximized to produce diesel fuel, the diesel and jet fuel both have lifecycle GHG emissions of 4,448 gCO_2e/mmBtu. For the same reasons, the lifecycle GHG emissions from the diesel and jet fuel will stay equivalent if we consider upstream GHG emissions, such as emissions associated with palm oil cultivation and land use change. Lifecycle GHG emissions from fuel distribution and use could be somewhat different for the diesel and jet fuel, but since these stages produce a relatively small share of the emissions related to the full fuel lifecycle, the overall differences will be quite small. The results presented below include emissions related to transporting palm oil-based diesel fuel.

We model the production technology for palm oil renewable diesel as mature and therefore have not projected in our assessment any significant improvements in plant technology.

Unanticipated energy saving improvements would improve GHG performance of the fuel pathway, but at this time we do not have a strong technical basis for including any such improvements.

Figure II-2 summarizes the results of our modeling of palm oil renewable diesel, with fuel production emissions allocated between the diesel fuel and jet fuel outputs and displacement credit given for the naphtha output. It shows the percent difference between lifecycle GHG emissions for palm oil renewable diesel produced in 2022 and those for the statutory petroleum baseline. Lifecycle GHG emissions equivalent to the diesel baseline are represented on the graph by the zero on the X-axis. The results for palm oil renewable diesel are that the midpoint of the range of results is an 11% reduction in GHG emissions compared to the diesel fuel baseline.[70] As with Figure II-1, the range of results shown in Figure II-2 is based on our assessment of uncertainty regarding the location and types of land that may be impacted as well as the GHG impacts associated with these land use changes. These results, if finalized, would justify our determination that fuel produced by the modeled palm oil renewable diesel pathway fails to meet the 20% reduction threshold required for the generation of conventional renewable fuel RINs.

[70] The 95% confidence interval around that midpoint results in range of a 10% increase to a 30% reduction compared to the 2005 diesel fuel baseline.

Figure II-2. Distribution of Results for Palm Oil Renewable Diesel Produced Via Hydrotreating

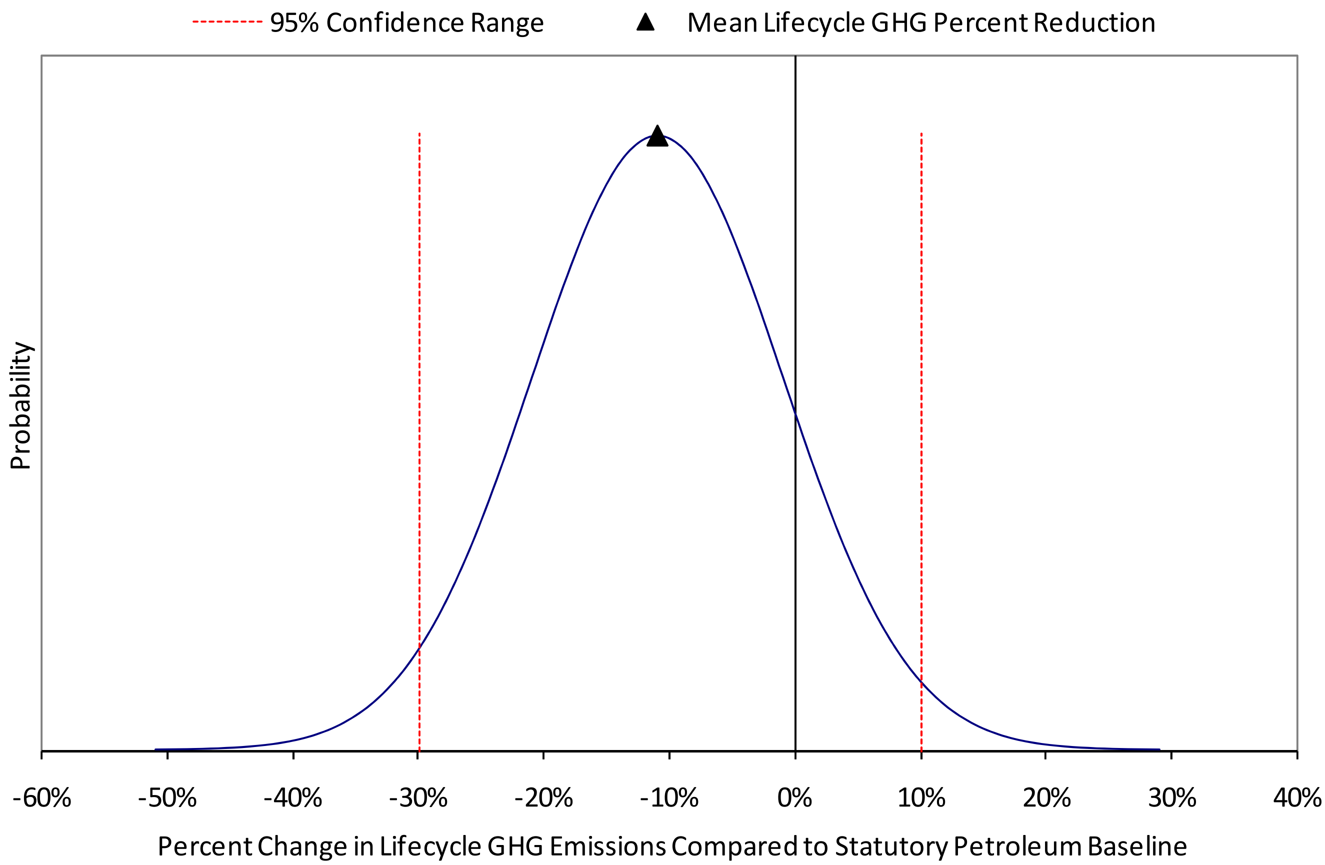

Table II-11 breaks down by stage the lifecycle GHG emissions for palm oil renewable diesel in 2022 and the statutory diesel baseline.[71] This table demonstrates the contribution of each stage and its relative significance. Results are included using our mid-point estimate of land use change emissions, as well as with the low and high end of the 95% confidence interval. Net agricultural emissions include impacts related to changes in crop inputs, such as fertilizer, energy used in agriculture, livestock production and other agricultural changes in the scenarios modeled. Land use change emissions are discussed above in Section II.A.4. Emissions from

[71] In the table totals may not sum due to rounding.

fuel production include emissions from palm oil mills, palm kernel mills and the hydrotreating process to produce renewable biodiesel. Fuel and feedstock transport includes emissions from transporting fresh fruit bunches, palm kernels, crude palm oil and finished renewable diesel along each stage of the lifecycle.

Table II-11. Lifecycle GHG Emissions for Palm Oil Renewable Diesel (kgCO_2e / mmBtu)

Fuel Type	Palm Oil Renewable Diesel	2005 Diesel Baseline
Net Agriculture (w/o land use change)	5	
Land Use Change, Mean *(Low/High)*	47 *(28/67)*	
Fuel Production	31	18
Fuel and Feedstock Transport	4	*
Tailpipe Emissions	1	79
Total Emissions, Mean *(Low/High)*	**87 *(68/107)***	**97**
Midpoint Lifecycle GHG Percent Reduction Compared to Petroleum Baseline	**11%**	

*Emissions included in fuel production stage.

The docket includes a memorandum which summarizes relevant materials used for the palm oil renewable diesel analysis. Described in the memorandum, for example, are the input and assumptions document and detailed results spreadsheets (e.g., agricultural impacts, agricultural energy use, FAPRI-CARD model results) used to generate the results presented. The input and assumptions document available through the docket describes many aspects of our analysis, include our co-product accounting approach. EPA invites comment on all aspects of its modeling of palm oil renewable diesel including all assumptions made and modeling inputs.

D. Consideration of Lifecycle Analysis Results

1. Implications for Threshold Determinations

As discussed above, EPA's analysis of the two types of biofuel shows that, based on the mid-point of the range of results, biodiesel and renewable diesel produced from palm oil have estimated lifecycle GHG emission reductions of 17% and 11% respectively compared to the statutory petroleum baseline used in the RFS program. The results for palm oil biodiesel and for palm oil renewable diesel, if finalized, would justify treating these fuel pathways as failing to meet the minimum 20% lifecycle GHG reduction requirement in the RFS program for non-grandfathered biofuels.

Our analysis applies to the modeled palm oil biodiesel and palm oil renewable diesel pathways regardless of their country of origin (See 75 FR 14793 for a similar discussion regarding other pathways). We project that the vast majority of palm oil used to produce biofuels for use in the United States would be produced in Indonesia and Malaysia (See Table II-1). Although palm oil and palm oil biofuel production may occur in other countries that have not been specifically modeled, or may be supplied from countries in different proportions than we modeled, we anticipate their use would not impact our conclusions regarding the lifecycle GHG thresholds met by the palm oil biofuel pathways under consideration. The emissions of producing these fuels in other countries could be slightly higher or lower than what was modeled depending on a number of factors. Our analysis indicates that crop yields in other countries where palm oil would most likely be produced tend to be lower than Malaysia and Indonesia, pointing toward somewhat higher land use change and consequently potentially higher land use change GHG impacts. If the supply of palm oil from other countries were to reduce the amount of agricultural expansion in Indonesia and Malaysia, with potentially reduced amounts of peat soil drainage, as compared to the amount predicted in our modeling, this would tend to lower our estimate of GHG emissions per acre of land use change. Technologies for turning this palm oil into biofuel are well established and would be expected to be similar in different countries. Based on these offsetting land use impact factors, similar biofuel production technology, and the small amounts of palm oil for biofuel likely to come from other countries, we conclude that incorporating palm oil from other countries would not impact our threshold determinations.

2. Consideration of Uncertainty

Because of the inherent uncertainty and the state of evolving science regarding lifecycle analysis of biofuels, any threshold determinations that EPA makes for palm oil biodiesel and renewable diesel will be based on an approach that considers the weight of evidence currently available. For these two pathways the evidence considered includes the mid-point estimate as well as the range of results based on statistical uncertainty and sensitivity analyses conducted by the Agency. EPA will weigh all of the evidence available to it, while placing the greatest weight on the best-estimate value for the scenarios analyzed.

As part of our assessment of the two palm oil biofuel pathways we have identified key areas of uncertainty in our analysis. Although there is inherent uncertainty in all portions of the lifecycle modeling, we focused our uncertainty analysis on the factors that are the most uncertain and have the biggest impact on the results. For example, the energy and GHG emissions used by a natural gas-fired biodiesel plant to produce one gallon of biodiesel can be calculated through direct observations, though this will vary somewhat between individual facilities. The indirect, international emissions are the component of our analysis with the highest level of uncertainty. For example, identifying what type of land is converted internationally and the emissions associated with this land conversion are critical issues that have a large impact on the GHG emissions estimates. Therefore, we focused our efforts on the international indirect land use change emissions and worked to manage the uncertainty around those impacts in three ways: (1) getting the best information possible and updating our analysis to narrow the uncertainty, (2) performing sensitivity analysis around key factors to test the impact on the results, and (3) establishing reasonable ranges of uncertainty and using probability distributions within these ranges in threshold assessment.

Our analysis of land use change GHG emissions includes an assessment of uncertainty that focuses on two aspects of indirect land use change – the types of land converted and the GHG emissions associates with different types of land converted. These areas of uncertainty were estimated statistically using the Monte Carlo analysis methodology developed for the RFS2 final rule.[72] Figure II-1 and Figure II-2 show the results of our statistical uncertainty assessment. In analyzing both palm oil biofuel pathways, the midpoint results, and therefore the majority of

[72] The Monte Carlo analysis is described in EPA (2010a), Section 2.4.4.2.8

the scenarios analyzed, fail to meet the 20% lifecycle GHG reduction requirement for non-grandfathered renewable fuels.

We have also identified areas of uncertainty that are not explicitly addressed in our Monte Carlo analysis due to time considerations. These areas of uncertainty have been assessed with sensitivity analysis and qualitative inspection. A majority of the areas of uncertainty considered could result in higher actual lifecycle GHG emissions than estimated in our midpoint results. These aspects of our analysis include uncertainties regarding: the total area of projected incremental palm oil expansion; the percent of palm oil expansion impacting tropical peat swamp forests; and indirect emissions related to peat soil drainage, such as from an increased risk of forest fires or collateral drainage of nearby uncultivated land. For these areas of uncertainty it is our judgment that our midpoint estimates likely underestimate the actual amount of lifecycle GHG emissions, but it is unlikely that they overestimate the actual emissions. We have also identified a smaller number of uncertainties which could result in less actual emissions. For example, increased adoption of methane capture/use technologies at palm oil mills and future government restrictions on peat soil development would likely result in less actual emissions than estimated in our midpoint results. Regarding methane capture and use projections, we conducted sensitivity analysis assuming that all mills use closed digester tanks with 90% methane capture efficiency, and convert the methane to electricity with 34% efficiency for export to the grid. In this sensitivity scenario, the mid-point results for palm oil biodiesel and renewable diesel are 42% and 36% reductions compared to the diesel baseline, respectively. Thus, even in this very optimistic scenario, neither of the palm oil biofuel pathways analyzed achieves a 50% GHG reduction. Our consideration of uncertainties in our lifecycle assessments is described further in a reference document available through the public docket.

Based on the weight of evidence considered, and putting the most weight on our mid-point estimate results, the results of our analysis indicate that both palm oil based biofuels pathways would fail to qualify as meeting the minimum 20% GHG performance threshold for qualifying renewable fuel under the RFS program. This conclusion is supported by our midpoint estimates, our statistical assessment of land use change uncertainty, as well as our consideration of other areas of uncertainty. A majority of the areas of uncertainty that we have identified, and discussed above, would lead to higher actual lifecycle GHG emissions than estimated in our midpoint results. Some of these areas of uncertainty appear to be fairly likely to result in greater actual emissions and in some cases by a substantial amount. In comparison, we identified a smaller number of uncertainties which could result in less actual emissions, but these factors appear less likely to reduce emissions by an equivalent amount. Based on the results of our analysis and considering key areas of uncertainty, the minimum 20% lifecycle GHG reduction requirements for non-grandfathered fuels under the RFS program is not achieved for the palm oil biofuel pathways evaluated.

The docket for this NODA provides more details on all aspects of our analysis of palm oil biofuels. EPA invites comment on all aspects of its modeling of palm oil biodiesel and renewable diesel. We also invite comment on the consideration of uncertainty as it relates to making GHG threshold determinations.

Dated: December 14, 2011.

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Margo T. Oge,

Director, Office of Transportation & Air Quality

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